P 566/989

PHOSPHATE ROCK

By William F. Stowasser

1989

U.S. DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

I 28.37/2:

READEX FICHE best copy available

PHOSPHATE ROCK

U.S.
DEPARTMENT
OF THE
INTERIOR

Manuel Lujan, Jr.
Secretary

BUREAU
OF
MINES

T S Ary
Director

October 1990

Contents

Domestic Data Coverage 1
Legislation and Government Programs 1
Strategic Considerations 2
Issues 2
Production 2
  Florida and North Carolina 2
  Western States 3
Consumption and Uses 3
Stocks 4
Transportation 6
Prices 7
Foreign Trade 7
  Exports 7
  Imports 8
World Review 9
  Industry Structure 10
  Capacity 10
  Reserves 10
Outlook 11
Background 11
  Definitions 13
  Products for Trade and Industry 14
  Industry Structure 15
  Tariffs and Taxes 16
  Technology 16

COVER PHOTO:
Harvesting wheat.

Tables

Table 1.—Salient Phosphate Rock Statistics 1
Table 2.—Production of Phosphate Rock in the United States, by Region 3
Table 3.—U.S. Phosphate Rock Sold or Used Grade Distribution Pattern 4
Table 4.—Florida and North Carolina Phosphate Rock Sold or Used Grade Distribution Pattern 4
Table 5.—Tennessee and Western States Phosphate Rock Sold or Used Grade Distribution Pattern 4
Table 6.—Phosphate Rock Sold or Used by Producers in the United States, by Grade and Region 5
Table 7.—Phosphate Rock Sold or Used by Producers in the United States, by Use 5
Table 8.—Phosphate Rock Sold or Used by Producers in the United States, by Use and Region 6
Table 9.—Florida and North Carolina Phosphate Rock Sold or Used by Producers 6
Table 10.—Tennessee and Western States Phosphate Rock Sold or Used by Producers 7
Table 11.—Marketable Phosphate Rock Yearend Stocks 7
Table 12.—Time-Price Relationships for Phosphate Rock 7
Table 13.—Phosphate Rock Estimated Export Prices per Metric Ton, Unground, f.o.b. Vessel Tampa Range or Jacksonville, FL, by Grade 7
Table 14.—Moroccan Phosphate Rock Export Prices, U.S. Dollars per Metric Ton, f.a.s. Safi or Casablanca, by Grade 8
Table 15.—Price or Value of Florida and North Carolina Phosphate Rock, by Grade 8
Table 16.—Price or Value of Tennessee and Western States Phosphate Rock, by Grade 8
Table 17.—Price or Value of U.S. Phosphate Rock, by Grade 9
Table 18.—U.S. Exports of Ground Phosphate Rock, by Country 9
Table 19.—U.S. Exports of Unground Phosphate Rock, by Country 10
Table 20.—U.S. Exports of Superphosphates, More Than 40% P_2O_5, by Country 11
Table 21.—U.S. Exports of Superphosphates, Less Than 40% P_2O_5, by Country 11
Table 22.—U.S. Exports of Diammonium Phosphates, by Country 12
Table 23.—U.S. Exports of Monoammonium Phosphates, by Country 13
Table 24.—U.S. Exports of Phosphoric Acid, Less Than 65% P_2O_5, by Country 14
Table 25.—U.S. Exports of Elemental Phosphorus, by Country 14
Table 26.—U.S. Imports for Consumption of Phosphate Rock and Phosphate Materials 15
Table 27.—World Phosphate Rock Annual Production Capacity, December 31, 1989 Rated Capacity 16
Table 28.—U.S. Phosphate Rock Reserve and Reserve Base Estimates 16
Table 29.—World Phosphate Rock Reserve and Reserve Base 17
Table 30.—Phosphate Rock, Basic Slag, and Guano: World Production, by Country 18

For further information, please contact
The Branch of Industrial Minerals
The Division of Mineral Commodities
Bureau of Mines
2401 E St., NW, MS 5209
Washington, DC 20241-0001
Telephone: (202) 634-1190
FAX: (202) 634-4091

PHOSPHATE ROCK

By William F. Stowasser

Mr. Stowasser, a physical scientist with 19 years Bureau of Mines experience, has been the commodity specialist for phosphate rock since 1974. Domestic survey data were prepared by William Fields, mineral data assistant, and the international data table were prepared by Peter Roetzel, international data assistant.

Phosphate rock production in the United States increased almost 10% in 1989 over that of 1988. The production of 49,817,000 tons[1] was consumed in several markets. The estimated U.S. demand pattern was 19,180,000 tons used in domestically consumed fertilizer, 20,803,000 tons was converted to fertilizer and exported, 1,647,000 tons was used domestically in other than fertilizer applications, and 512,000 tons was exported as other than fertilizer chemicals.

The United States exported 7,842,000 tons of phosphate rock and imported 704,000 tons preserving the general trends of declining phosphate rock exports and increasing imports.

World production of phosphate rock was similar to that of 1988. Production remained at a plateau of about 162 million tons.

DOMESTIC DATA COVERAGE

Domestic production data for phosphate rock are developed by the Bureau of Mines from two separate voluntary surveys of U.S. operations. Typical of these surveys is the semiannual Phosphate Rock Survey. Of the 19 operations to which a survey request was sent, all responded, representing 100% of the U.S. production data shown in table 1.

LEGISLATION AND GOVERNMENT PROGRAMS

Section 3001(b)(3)(A)(ii) of the Resources Conservation and Recovery Act (RCRA), known as the Bevill Exclusion, excludes "solid waste from the extraction, beneficiation, and processing of ores and minerals" from regulation as hazardous waste under subtitle C of RCRA, pending completion of certain studies by the Environmental Protection Agency (EPA). In 1980, the EPA interpreted this exclusion on a temporary basis to encompass "solid waste from the exploration, mining, milling, smelting, and refining of ores and minerals." On September 1, 1989, EPA published the final criteria and took final action on all but 20 mineral processing waste streams. The wastes proposed for removal from the Bevill Exclusion were furnace offgas solids from elemental phosphorus production, phosphogypsum from phosphoric acid production, and furnace slag from elemental phosphorus production.

As of September 1, 1989, the status of previously proposed Bevill mineral processing wastes in the phosphoric

TABLE 1

SALIENT PHOSPHATE ROCK STATISTICS[1]

(Thousand metric tons and thousand dollars unless otherwise specified)

	1985	1986	1987	1988	1989
United States:					
Mine production (crude ore)	175,227	135,683	148,426	162,299	170,268
Marketable production	50,835	40,320	40,954	45,389	49,817
P_2O_5 content	15,634	12,248	12,470	13,833	15,116
Value	[2]$1,235,800	[2]$897,131	[2]$793,280	$887,809	$1,084,022
Average per metric ton[3]	$24.31	$22.25	$19.37	$19.56	$21.76
Sold or used by producers[4]	46,634	41,776	43,673	48,441	49,280
P_2O_5 content	14,363	12,750	13,286	14,760	14,935
Value	[2]$1,133,675	[2]$929,621	[2]$845,812	$947,721	$1,072,454
Average per metric ton[3,5]	$24.31	$22.25	$19.37	$19.56	$21.76
Exports[6]	9,136	7,848	8,454	8,092	7,842
P_2O_5 content	2,931	2,521	2,737	2,608	2,522
Value[2]	$263,631	$211,701	$194,691	$206,984	$227,272
Average per metric ton[3]	$28.86	$26.97	$23.03	$25.58	$28.98
Imports for consumption	[7]34	528	464	[r]676	705
C.i.f. value	$1,747	$25,435	$22,134	[r]$26,310	$29,878
Average per metric ton	[8]$51.54	[8]$48.18	$47.70	[r]$38.92	$42.44
Consumption[9]	37,532	34,456	35,683	41,022	42,143
Stocks, Dec. 31: Producers	15,534	13,277	10,884	9,323	11,027
World: Production	148,842	138,870	144,228	[p]163,673	[e]162,000

[e] Estimated. [p] Preliminary. [r] Revised.

[1] Data for the same items appearing in this and other tables may not reconcile because of manual or computer rounding.

[2] The total value is based on a weighted value.

[3] Computer-calculated average value based on the weighted sold or used values.

[4] Includes domestic sales and exports.

[5] Weighted average of sold or used values.

[6] Exports reported to the Bureau of Mines by companies.

[7] Bureau of the Census data, excluding reported Canadian and Israeli imports.

[8] Average unit value obtained from unrounded data.

[9] Expressed as sold or used plus imports minus exports.

acid and elemental phosphorus sectors was as follows:

1. Furnace off-gas solids was conditionally retained because it passed high-volume criteria.
2. Furnace scrubber blowdown was removed because of low volume.
3. Process wastewater was removed because of low volume.
4. Slag was retained because it passed all criteria.
5. Phosphogypsum was retained because of high volume.
6. Process wastewater was conditionally retained because of high volume.

As of September 25, 1989, the proposed status of each of the phosphate commodity wastes and the basis for each were as follows:

1. Elemental furnace off-gas solids from 5 operations was not retained within the Bevill Exclusion.
2. Phosphoric acid process wastewater from 28 operations was retained within the Bevill Exclusion.

The Office of Radiation Programs, EPA, ruled that conditionally and pending further studies, a reduction of radon emissions from phosphogypsum stacks would not be required. The emissions were within the acceptable risk of 1 cancer death per year for every 10,000 people from radon-222 gas from an active phosphogypsum stack. The maximum mortality risk from radioactive particulates was estimated at about 2 in 1,000,000.

STRATEGIC CONSIDERATIONS

Phosphate rock is not strategically stockpiled. The United States is a net exporter of both phosphate rock and phosphate chemicals. There is concern, however, over the adequacy of domestic supply in future years when the deposits of phosphate rock in Florida that have sustained domestic and export markets for many decades are mined out. Phosphate rock deposits in Florida, after 100 years of production, have a limited supply of high-quality reserves remaining. (The subject of phosphate rock reserves is discussed in this publication under reserves.) A review of mine production plans of Florida mines shows that as years progress, the supply of phosphate rock from remaining mines will decline. The rate of decline will depend on future mining rates, if environmentally sensitive wetlands and hardwood stands will be permitted and mined, if technology to improve the quality of phosphate rock can be developed, and if the economics of mining and processing phosphate rock become sufficiently attractive to develop new mines in Florida and expand the capacity of the mine in North Carolina.

Raw material demand for phosphate rock is closely associated with production levels in the world's fertilizer industries. The demand for agricultural products is tied to population. A world population over 5 billion in 1989 is forecasted to reach 6.2 billion in the year 2000.

The increase in population and an anticipated increase in per capita income will increase the demand for food, feed, and fiber, increasing the pressure on world agriculture to produce the necessary quantities of these products. Programs and policies are needed to promote growth in fertilizer application and food production so that people, particularly in developing countries, can have higher nutritional levels in the year 2000.

ISSUES

The demand for U.S. phosphate rock in 1989 was more than expected when India discontinued receiving Moroccan phosphoric acid and purchased an additional 1.5 to 2 million metric tons of diammonium phosphate (DAP). The tonnage was supplied for the most part by U.S. producers, and with this windfall, prices were sustained during the main shipping period of the year. As shipments to India declined, prices for DAP fell, indicating overcapacity of the U.S. DAP industry. The decline in prices forced high-cost plants to close or reduce production. Overcapacity in the U.S. DAP industry was the reason, and it was forecasted that India's imports of DAP will be less in 1990. Low DAP prices will probably encourage sales into some areas; however, the quantities sold were not expected to increase in 1990 over that of 1989. Closing DAP plants in the United States may not resolve the issue as Morocco plans to double its DAP capacity at Jorf Lasfar in the next few years.

After 100 years of production from Florida's Bone Valley Formation, it is difficult to accept the prognosis of a decline in the supply of phosphate rock from the region. This decline was particularly difficult to accept in 1989 when efforts were made to replenish domestic grain stocks, depleted by the drought in 1988, and supply an exceptionally strong export market for phosphate fertilizers. At issue is the development of replacement mines to offset production losses as phosphate rock deposits are mined out in Florida. There are a limited number of remaining deposits from which acceptable products could be produced in Florida. Investors have been reluctant to develop new mines in Florida without assurance of a profitable return. Current selling prices and estimated production costs from a potential new mine do not encourage investments.

The future supply of phosphate rock could be increased by investment in North Carolina, where large reserves are available, to accommodate a mine expansion. Expansion of existing mines in Florida does not appear at this time to be economically feasible, and quality reserves are limited.

PRODUCTION

Compared with 1988, domestic production of marketable phosphate rock increased 10% in 1989 to 49.8 million tons. Production was 2 million tons higher than planned by producers as they responded to improved demand in the domestic and export sectors for phosphate fertilizers and elemental phosphorus derivatives. Most of the increased supply originated in Florida. Of the total U.S. production, Florida and North Carolina supplied 88%, and the balance was produced in Idaho, Montana, Tennessee, and Utah.

Florida and North Carolina

Phosphate rock was produced in Florida by Agrico Mining Co., a division of Agrico Chemical Co., owned by Freeport-McMoRan Resource Partners L.P.; CF Industries Inc.; Estech Inc., owned by C&G Holdings Inc.; Gardinier Inc.,

80% ownership by Cargill, Inc.; IMC Fertilizer Inc. (IMC); Mobil Mining and Minerals Co.; U.S. Agri-Chemicals Corp.; Seminole Fertilizer Corp., owned by Tosco Corp.; and Occidental Chemical Agricultural Products Inc. in northern Florida. Nu-Gulf Industries Inc., a subsidiary of Nu-West Industries Inc., shipped phosphate rock from inventory but did not produce it in 1989.

Low-fluorine soft phosphate rock was recovered from hard phosphate rock tailing ponds in north-central Florida by Manko Co., Howard Phosphate Co., and Loncala Phosphate Co.

Texasgulf Inc., a subsidiary of Elf Aquitaine Inc., was the only producer of phosphate rock in North Carolina. Studies to deepen the harbor and channel at Morehead City, NC, for navigation by deeper draft vessels were in progress. Texasgulf produced phosphate rock from the Lee Creek Mine adjacent to the Pamlico River.

Western States

Phosphate rock was mined in Idaho, Montana, and Utah. Nu-West produced phosphate rock from a number of deposits in Idaho. The phosphate rock was beneficiated and calcined at Conda, ID. J. R. Simplot Co. produced phosphate rock from the Gay Mine, Fort Hall Indian Reservation, and the Smoky Canyon Mine, Caribou National Forest. The Gay Mine's main bed phosphate rock was used by Simplot, and the lower-grade shale was used in FMC Corp.'s electric furnaces. Monsanto Co. supplied its Soda Spring, ID, electric furnaces from the Enoch Valley Mine. Rhône-Poulenc Basic Chemicals Co. operated the Wooley Valley Mine, ID, to supply phosphate rock to its Silver Bow, MT, electric furnaces. Cominco American Inc. operated an underground mine, beneficiation, and drying plant near Garrison, MT. The dried product was exported to Canada. Chevron Resources Co. produced phosphate rock from the Vernal Mine, UT. It was transported by pipeline to Rock Springs, WY.

CONSUMPTION AND USES

The demand pattern for phosphate rock in the United States was stable during the past decade. Between 85% and 90% of phosphate rock consumed was used to produce phosphate fertilizer for domestic or export markets. Frequently, over 50% of the manufactured fertilizer was consumed domestically; however, there were several years during the past decade that fertilizer exports exceeded domestic consumption.

Phosphate rock exports have declined from a 14 million ton-per-year level in 1979 to about 8 million tons-per-year in recent years as the industry

TABLE 2

PRODUCTION OF PHOSPHATE ROCK IN THE UNITED STATES, BY REGION[1]

(Thousand metric tons and thousand dollars)

Region	Mine production		Marketable production							Ending stocks
			Used directly		Beneficiated		Totals[2]			
	Rock	P_2O_5 content	Rock	P_2O_5 content	Rock	P_2O_5 content	Rock	P_2O_5 content	Value[3,4]	
1988:	162,299	r20,951	3,832	1,045	41,557	12,787	45,389	13,823	887,809	9,323
1989:										
January–June										
Florida and North Carolina	r92,616	r16,279	266	81	r22,993	r7,029	r23,259	r7,111	r500,958	r9,954
Idaho, Montana, Tennessee, and Utah	4,912	1,225	1,555	416	1,412	431	2,967	847	r64,702	1,757
Total[2]	r97,527	r17,505	1,821	497	r24,405	r7,461	r26,226	r7,958	r565,660	r11,711
July–December										
Florida and North Carolina	68,115	8,840	292	88	20,088	6,155	20,380	6,242	458,657	9,541
Idaho, Montana, Tennessee, and Utah	4,626	1,145	1,785	473	1,426	442	3,211	916	58,479	1,486
Total[2]	72,740	9,986	2,078	561	21,514	6,597	23,591	7,158	517,137	11,027
Grand total[2]	170,268	27,490	3,899	1,058	45,919	14,058	49,817	15,116	1,084,022	XX

r Revised. XX Not applicable.

[1] Data for the same items appearing in this and other tables may not reconcile because of manual/computer rounding.

[2] Data may not add to totals shown because of independent rounding.

[3] Computer-calculated value based on the weighted sold or used value.

[4] The total value is based on a weighted value. The total value does not equal the sum of the regional or 1/2-year totals because weighted regional or overall 1/2-year unit values were used in the calculations. The regional and 1/2-year values are approximate.

converted more phosphate rock to higher value intermediates or finished fertilizer. The emergence of phosphate fertilizer industries in developing countries with domestic phosphate rock deposits caused major changes in trade patterns. Countries with indigenous phosphate rock deposits like Jordan, Morocco, Senegal, and Tunisia established fertilizer plants that competed in markets throughout the world. Phosphate rock imports, particularly shipments from Morocco and Togo, to plants on the Mississippi River increased in the last years of the decade to similar levels that existed at the beginning of the decade. The resumption of substantial imports was prompted by a need for higher quality phosphate rock than was available domestically to produce high purity fertilizers.

The balance of phosphate rock was consumed with silica and coke in electric furnaces to produce elemental phosphorus. Elemental phosphorus was used to produce high-purity phosphoric acid, salts, and phosphorus chemicals for industry and home consumption. These included detergents and cleaners, chemicals for food and beverages, and metal-treating chemicals.

The detergent builder, sodium tripolyphosphate, was the principal derivative of elemental phosphorus. The manufacture of thermal or furnace phosphoric acid accounted for 80% to 85% of U.S. elemental phosphorus production. About 10% of the elemental phosphorus production was used to produce phosphorus pentasulfide, phosphorus pentoxide, and phosphorus trichloride. About 50% of the elemental phosphorus produced was used to manufacture sodium tripolyphosphate.

The gradual decline in elemental phosphorus production and the quantity of phosphate rock consumed in electric furnaces during the past decade was caused by banning phosphates from home laundry products in some areas of the country. Several companies decided to construct plants to produce higher quality, lower cost, wet-process phosphorus acid purification plants that would produce a purified acid to replace thermal acid in food and detergent grade products. Thermal acid will continue to be used by semiconductor manufacturers and in other ultrahigh-purity markets. Where thermal acid competes with purified wet-process acid, lower cost wet-process acid will probably be the choice selected in the future.

TABLE 3

U.S. PHOSPHATE ROCK SOLD OR USED GRADE DISTRIBUTION PATTERN

Distribution (percentage)

Grade (percent BPL[1] content)	Distribution (percentage)				
	1985[2]	1986	1987	1988	1989[2]
74 or more	2.9	4.5	3.4	2.0	0.8
72 to less than 74	4.2	4.0	5.4	5.6	7.4
70 to less than 72	12.0	7.8	7.1	8.8	6.2
66 to less than 70	62.9	57.5	61.6	59.7	61.7
60 to less than 66	13.1	20.3	17.5	14.9	19.3
Less than 60	4.8	5.9	5.0	9.0	4.7

[1] 1.0% BPL (bone phosphate of lime or tricalcium phosphate) = 0.458% P_2O_5.
[2] Data do not add to 100% because of independent rounding.

TABLE 4

FLORIDA AND NORTH CAROLINA PHOSPHATE ROCK SOLD OR USED GRADE DISTRIBUTION PATTERN

Grade (percent BPL[1] content)	Distribution (percentage)				
	1985[2]	1986	1987	1988	1989
74 or more	3.4	5.1	3.8	2.3	0.9
72 to less than 74	4.8	4.6	6.0	6.4	7.6
70 to less than 72	12.6	9.0	7.6	8.2	6.2
66 to less than 70	65.9	60.7	65.3	64.0	66.4
60 to less than 66	12.8	20.6	17.3	14.4	18.9
Less than 60	.6	—	(3)	4.7	—

[1] 1.0% BPL (bone phosphate of lime or tricalcium phosphate) = 0.458% P_2O_5.
[2] Data do not add to 100% because of independent rounding.
[3] Less than 0.1 of 1%.

STOCKS

Phosphate rock was inventoried in wet rock piles adjacent to the beneficiation plants in Florida and North Carolina. The stocks were reclaimed for drying or calcining for export or for wet-grinding before wet-process phosphoric acid manufacture. Industry stocks peaked in 1981 when about 20 million tons was reported at yearend. Since 1981, the phosphate rock inventory tonnage declined each year, reaching 9.3 million tons in 1988. In the Western States, where the climate made it diffi-

TABLE 5

TENNESSEE AND WESTERN STATES PHOSPHATE ROCK SOLD OR USED GRADE DISTRIBUTION PATTERN

Grade (percent BPL[1] content)	Distribution (percentage)		
	1987	1988	1989
72 to less than 74	—	—	5.6
70 to less than 72	3.5	12.5	6.1
66 to less than 70	33.9	29.8	28.6
60 to less than 66	19.3	18.2	21.8
Less than 60	43.3	39.5	37.9

[1] 1.0% BPL (bone phosphate of lime or tricalcium phosphate) = 0.458% P_2O_5.

TABLE 6

PHOSPHATE ROCK SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY GRADE AND REGION[1]

(Thousand metric tons and thousand dollars)

Grade (percent BPL[2] content)	Florida and North Carolina			Tennessee and Western States[3]			Total		
	Rock	P_2O_5 content	Value[4 5]	Rock	P_2O_5 content	Value[4 5]	Rock	P_2O_5 content	Value[4 5]
January–June 1988	20,472	6,275	369,224	2,850	817	53,973	23,322	7,092	423,197
July–December 1988	21,922	6,762	480,738	3,197	907	63,786	25,119	7,669	524,524
January–June 1989:									
74 or more	r205	r70	r6,440	—	—	—	r205	r70	r6,440
72 to less than 74	r2,385	r796	r67,575	—	—	—	r2,385	r796	r67,575
70 to less than 72	1,059	345	29,654	376	122	13,690	1,435	467	43,344
66 to less than 70	13,635	4,194	270,008	889	275	26,831	14,524	4,469	296,839
60 to less than 66	r4,790	r1,358	r106,283	582	166	6,314	r5,372	r1,524	r112,597
Below 60	—	—	—	871	221	13,974	871	221	13,974
Total[6]	r22,074	r6,763	r479,960	2,718	784	60,809	r24,792	r7,547	r540,769
July–December 1989:									
74 or more	189	66	5,332	—	—	—	189	66	5,332
72 to less than 74	894	300	28,489	346	116	12,776	1,240	416	41,265
70 to less than 72	1,611	522	47,503	—	—	—	1,611	522	47,503
66 to less than 70	15,005	4,600	311,557	869	269	21,631	15,874	4,869	333,188
60 to less than 66	3,357	934	79,153	757	213	9,237	4,114	1,147	88,390
Below 60	—	—	—	1,459	370	16,006	1,459	370	16,006
Total[6]	21,056	6,422	472,034	3,431	968	59,650	24,487	7,390	531,684

r Revised.
[1] Data for the same items appearing in this and other tables may not reconcile because of manual or computer rounding.
[2] 1.0% BPL (bone phosphate of lime or tricalcium phosphate) = 0.458% P_2O_5.
[3] Includes Idaho, Montana, and Utah.
[4] F.o.b. mine.
[5] The total value is based on a weighted value. The total value does not equal the sum of the regional totals because weighted regional unit values were used in the calculations. The regional values are approximate.
[6] Data may not add to totals shown because of independent rounding.

TABLE 7

PHOSPHATE ROCK SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE[1]

(Thousand metric tons)

Use	1988 total		1989					
			January–June		July–December		Total[2]	
	Rock	P_2O_5 content	Rock	P_2O_5 content	Rock	P_2O_5 content	Rock	P_2O_5 content
Domestic:[3]								
Wet-process phosphoric acid	36,721	11,083	r19,017	r5,732	18,914	5,662	37,931	11,394
Normal superphosphate	r840	r325	r384	r125	553	172	937	297
Triple superphosphate	r641	r159	r234	r77	176	60	410	137
Defluorinated rock	66	22	—	—	—	—	—	—
Direct applications	1	(4)	2	1	1	—	3	1
Elemental phosphorus	2,044	553	917	250	1,205	325	2,122	575
Ferrophosphorus	36	9	18	4	19	5	37	9
Total[2]	40,349	12,152	r20,571	r6,189	20,866	6,225	41,437	12,413
Exports[5]	8,092	2,608	4,222	1,358	3,620	1,164	7,842	2,522
Grand total[2]	48,441	14,760	r24,793	r7,546	24,487	7,389	49,280	14,935

r Revised.
[1] Data for the same items appearing in this and other tables may not reconcile because of manual or computer rounding.
[2] Data may not add to totals shown because of independent rounding.
[3] Includes rock converted to products and exported.
[4] Less than 1/2 unit.
[5] Exports reported to the Bureau of Mines by companies.

TABLE 8

PHOSPHATE ROCK SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE AND REGION[1]

(Thousand metric tons)

Use	Florida and North Carolina		Tennessee and Western States[2]		Total[3]	
	Rock	P_2O_5 content	Rock	P_2O_5 content	Rock	P_2O_5 content
1988:	42,395	13,036	6,047	1,723	48,441	14,760
1989:						
January–June:						
Domestic:[4]						
Agricultural	r17,943	r5,434	1,693	501	r19,636	r5,934
Industrial	11	3	924	252	935	255
Subtotal	r17,954	r5,437	2,617	753	r20,571	r6,189
Exports[5]	4,120	1,326	102	32	4,222	1,358
Total[3]	r22,074	r6,763	2,719	785	r24,793	r7,547
July–December:						
Domestic:[4]						
Agricultural	17,473	5,269	2,171	626	19,643	5,894
Industrial	34	10	1,190	320	1,223	330
Subtotal	17,507	5,279	3,361	946	20,866	6,224
Exports[5]	3,549	1,143	71	21	3,620	1,164
Total[3]	21,056	6,422	3,432	967	24,486	7,388
Grand total[3]	43,130	13,185	6,151	1,752	49,279	14,935

r Revised.
[1] Data for the same items appearing in this and other tables may not reconcile because of manual or computer rounding.
[2] Includes Idaho, Montana, and Utah.
[3] Data may not add to totals shown because of independent rounding.
[4] Includes rock converted to products and exported.
[5] Exports reported to the Bureau of Mines by companies.

TABLE 9

FLORIDA AND NORTH CAROLINA PHOSPHATE ROCK SOLD OR USED BY PRODUCERS[1]

Year	Rock (thousand metric tons)	P_2O_5 content (thousand metric tons)	Value	
			Total[2] (thousands)	Average per ton f.o.b mine
1985	40,857	12,702	$972,748	$23.81
1986	36,333	11,236	810,429	22.31
1987	38,692	11,891	765,061	19.77
1988	42,395	13,036	829,963	19.58
1989	43,129	13,184	951,995	22.07

[1] Data for the same items appearing in this or other tables may not reconcile because of manual or computer rounding.
[2] The total value is based on a weighted value.

cult to unload frozen ore from trucks or rail cars, ore was stockpiled near the electric furnaces and chemical plants to permit year-round production.

During 1989, stock levels were about 9.5 million tons in January, 10.9 million tons in June, and stabilized at about 11 million tons for the balance of the year.

TRANSPORTATION

Phosphate rock was moved by rail from production centers in central and north Florida to terminals on Hillsborough Bay, FL and in Jacksonville, FL. The CSX Transportation Railroad moved phosphate rock from central Florida to Eastern Associated Terminals Co., Rockport Phosphate Terminal, International Minerals & Chemical Phosphate Terminal Co., and Agrico's Big Bend Terminal. Phosphate rock was shipped in bulk carriers to ports around the world and barged from Hillsborough Bay to chemical fertilizer plants on the Mississippi River. Freight, loading, and weighing charges were components of the cost of transporting phosphate rock from mine to vessel in central Florida. In 1974, the cumulative cost was $2.20 per ton. By 1990, the total cost increased to $6.98 per ton plus a Rockport Phosphate Terminal improvement charge of $0.36 per ton. Weighing charges were available at the shipper's request that reduced the cost from $0.22 per ton to about $0.02 per ton for a 20,000 ton cargo.

In north Florida, the Norfolk Southern Railroad transported phosphate rock from mine to vessel at Jacksonville, FL at a total cost of $9.08 per ton.

Specially designed barges with a capacity of 2,431 tons moved phosphate rock from the Lee Creek Mine to the Morehead City Port Terminal. The barge's capacity can move more than 15,400 tons every 3 days over the 93-kilometer section of the intercoastal waterway. Self-unloading barges discharged to conveyors for either direct delivery to a traveling shiploader or to a storage building. In Tennessee and the Western States, phosphate rock was moved by rail or truck from mine to beneficiation plant. Recently, two companies have installed slurry pipelines to convey concentrates to chemical fertilizer plants.

TABLE 10

TENNESSEE AND WESTERN STATES[1] PHOSPHATE ROCK SOLD OR USED BY PRODUCERS[2]

Year	Rock (thousand metric tons)	P_2O_5 content (thousand metric tons)	Value	
			Total[3] (thousands)	Average per ton f.o.b. mine
1985[4]	NA	NA	NA	NA
1986	5,443	1,515	$119,192	$21.90
1987	4,981	1,395	80,751	16.21
1988	6,047	1,723	117,758	19.47
1989	6,151	1,751	120,459	19.58

NA Not available.
[1] Includes Idaho, Montana, and Utah.
[2] Data for the same items appearing in this and other tables may not reconcile because of manual or computer rounding.
[3] The total value is based on a weighted value.
[4] Data for Tennessee and Western States were reported separately in the 1985 Minerals Yearbook chapter.

PRICES

The price or value of phosphate rock was obtained by semiannually surveying the industry to obtain domestic and export prices, f.o.b. mine, from each company in the United States. Price or value was obtained for each grade of phosphate rock produced by each company. Weighted averages were calculated for each grade and market. The average composite domestic and export f.o.b. actual mine price, dollars per ton, are shown in table 12.

The selling price of phosphate rock is negotiated between the buyer and seller. If exported from Tampa or Jacksonville, FL, the price included a freight, loading, and weighing cost of $6.53 per ton and $8.82 per ton, respectively. The severance tax included in the export price was $1.54 per ton.

TABLE 11

MARKETABLE PHOSPHATE ROCK YEAREND STOCKS

(Million metric tons)

Year	Quantity
1980	13.7
1981	19.6
1982	18.3
1983	14.5
1984	11.9
1985	15.5
1986	13.3
1987	10.9
1988	9.3
1989	11.0

FOREIGN TRADE

Exports

The United States was a net exporter of phosphate rock in 1989. The demand for phosphate rock was principally tied to the demand of downstream phosphate fertilizer industries. India has, in past years, purchased phosphoric acid from Morocco. In a dispute over pricing, India stopped purchasing phosphoric acid and manufacturing DAP. It chose instead to purchase about 2.5 million tons of DAP, which was, for the most part, supplied by United States producers. In addition, shipments of DAP to China were 2.3 million tons. With large volumes being absorbed by the export market, plants operated in excess of 90% of capacity in the United States. It is probable that exported DAP will total about 8.3 million tons, the highest level achieved in any prior year.

Exports of triple superphosphate declined for the fifth consecutive year to

TABLE 12

TIME-PRICE RELATIONSHIPS FOR PHOSPHATE ROCK[1]

(Dollars per metric ton)

Year	Actual prices	Based on constant 1982 dollars
1969	6.14	15.43
1970	5.80	13.81
1971	5.80	13.06
1972	5.62	12.09
1973	6.24	12.61
1974	12.10	22.41
1975	25.35	42.75
1976	21.26	33.69
1977	17.39	25.84
1978	18.56	25.71
1979	20.04	25.50
1980	22.78	26.58
1981	26.63	28.33
1982	25.52	25.52
1983	23.97	23.07
1984	23.99	22.27
1985	24.31	21.92
1986	22.25	19.55
1987	19.37	17.34
1988	19.56	16.08
1989	21.76	17.23

[1] Average annual U.S. producer domestic and export price, f.o.b. mine.

TABLE 13

PHOSPHATE ROCK ESTIMATED EXPORT PRICES[1] PER METRIC TON, UNGROUND, F.O.B. VESSEL TAMPA RANGE OR JACKSONVILLE, FL, BY GRADE

Grade (percent BPL[2] content)	1986[3]	1987[4]	1988[5]	1989[6]
75	$33.00	$32.00	$33.00	$38.00
72	31.00	29.00	31.00	35.50
70	27.00	27.50	28.00	32.00
68	25.50	24.00	26.00	31.00

[1] Prices include severance taxes, rail freight costs from mine to port, and port loading and weighing charges.
[2] 1.0% BPL (bone phosphate of lime or tricalcium phosphate) = 0.458% P_2O_5.
[3] Estimated selling price including $2.51 severance tax.
[4] Estimated selling price including $2.46 severance tax.
[5] Estimated selling price including $1.49 severance tax.
[6] Estimated selling price including $1.54 severance tax.

TABLE 14

MOROCCAN PHOSPHATE ROCK EXPORT PRICES, U.S. DOLLARS PER METRIC TON, F.A.S. SAFI OR CASABLANCA,[e] BY GRADE

Grade (percent BPL[1] content)	1986	1987	1988	1989
Khouribga:				
76 to 77	45.00	42.00	45.00	49.00
70 to 71	36.00	34.00	38.00	42.00
Youssoufia:				
74 to 75	40.50	39.50	45.00	49.00
68 to 69	30.50	30.00	34.00	37.00

[e] Estimated.
[1] 1.0% BPL (bone phosphate of lime or tricalcium phosphate) = 0.458% P_2O_5.

the range of 700 to 900 thousand tons.

Phosphate rock exports were 7.8 million tons, continuing the trend of gradually declining tonnages. After exports peaked in 1979 at 14 million tons, phosphate rock exports declined, and except for a small improvement in 1983, the trend persisted in recent years. The gradual loss of this market was attributed to converting more phosphate rock to higher value products, intense competition from other producing countries offering high-quality phosphate rock and positioned closer to markets than U.S. exporters, and the inability of U.S. companies to export phosphate rock of competitive grade and quality. Although the U.S. industry's supply problem will persist, overcapacity in all phosphate commodity lines will probably remain with the industry in the near term.

Imports

Phosphate rock imports had reached levels of 500 to 900 tons from 1978–80 when a company imported phosphate rock while developing its own mine. From 1981 through 1985, imports declined to a level of 9 to 34 thousand tons of low-fluorine material. Imports significantly increased to the 500 to 700 thousand ton level from 1986 through 1989. High-quality and grade phosphate rock was imported to satisfy a demand for phosphate rock that was unavailable domestically. It is probable that phosphate rock imports will increase in the future to plants in the United States located on water and with limited supplies of domestic high-grade and quality phosphate rock.

TABLE 15

PRICE OR VALUE OF FLORIDA AND NORTH CAROLINA PHOSPHATE ROCK, BY GRADE

(Dollars per metric ton, f.o.b. mine)

Grade (percent BPL[1] content)	1988			1989		
	Domestic	Export	Average	Domestic	Export	Average
74 or more	29.40	30.51	30.15	27.70	38.63	29.87
72 to less than 74	20.31	26.35	24.57	25.73	30.57	29.29
70 to less than 72	25.97	27.30	26.92	25.04	29.47	28.90
66 to less than 70	16.94	22.16	17.28	19.68	26.73	20.31
60 to less than 66	18.67	18.59	18.66	22.83	20.82	22.76
Less than 60	27.56	—	27.56	—	—	—
Average	18.29	25.24	19.58	20.65	28.67	22.07

[1] 1.0% BPL (bone phosphate of lime or tricalcium phosphate) = 0.458% P_2O_5.

TABLE 16

PRICE OR VALUE OF TENNESSEE AND WESTERN STATES[1] PHOSPHATE ROCK, BY GRADE

(Dollars per metric ton, f.o.b. mine)

Grade (percent BPL[2] content)	1988			1989		
	Domestic	Export	Average	Domestic	Export	Average
72 to less than 74	—	—	—	36.93	—	36.93
70 to less than 72	36.38	—	36.38	36.38	—	36.38
66 to less than 70	27.33	38.08	28.60	26.50	44.88	27.56
60 to less than 66	10.53	—	10.53	10.02	40.00	11.61
Less than 60	11.35	—	11.35	12.87	—	12.87
Average	18.79	38.08	19.47	18.91	42.87	19.58

[1] Includes Idaho, Montana, and Utah.
[2] 1.0% BPL (bone phosphate of lime or tricalcium phosphate) = 0.458% P_2O_5.

TABLE 17

PRICE OR VALUE OF U.S PHOSPHATE ROCK, BY GRADE

(Dollars per metric ton, f.o.b. mine)

Grade (percent BPL[1] content)	1988			1989		
	Domestic	Export	Average	Domestic	Export	Average
74 or more	29.40	30.51	30.15	27.70	38.63	29.87
72 to less than 74	20.31	26.35	24.57	28.93	30.57	30.02
70 to less than 72	30.45	27.30	28.60	30.99	29.47	29.83
66 to less than 70	17.57	23.54	18.08	20.08	27.42	20.73
60 to less than 66	17.33	18.59	17.43	21.05	24.61	21.19
Less than 60	18.71	—	18.71	12.87	—	12.87
Average	18.36	25.58	19.56	20.40	28.98	21.76

[1] 1.0% BPL (bone phosphate of lime or tricalcium phosphate) = 0.458% P_2O_5.

WORLD REVIEW

Phosphate rock production was maintained at about 162 million tons. Production was maintained from existing mines and from reactivating several that were closed. Not only were no new mines producing in 1989, there were no announcements of new mine development during the year. In the United States, demand for downstream products actually increased, but producers oversupplied the market in anticipation of an 8% to 10% growth rate after the drought of 1988. The oversupply caused DAP prices to drop after the Indian market was supplied.

The United States share of world production of phosphate rock declined to about 30%. The world supply of phosphate rock again exceeded demand allowing only a modest increase in prices. The Four Corners Mine in central Florida was restarted at the beginning of the year. The Wingate Creek Mine remained closed, and several other mines were scheduled to close in 1990 and 1991 as the deposits were mined out.

The principal producing countries in decreasing order of production were the United States, the U.S.S.R., Morocco, China, Tunisia, Jordan, Brazil, Togo, and the Republic of South Africa. No new mines were commissioned during the year. Production increases were achieved from existing mines.

Industry Structure

There were no significant changes in the structure of the phosphate industry

TABLE 18

U.S. EXPORTS OF GROUND PHOSPHATE ROCK, BY COUNTRY

(Thousand metric tons and thousand dollars)

(HTS No. 2510.20.0000)[1]

Country	1988		1989	
	Quantity[2]	Value	Quantity	Value
Australia	283		5	
Austria	62		—	
Belgium-Luxembourg	388		—	
Brazil	151		—	
Canada	1,186		165	
Finland	85		—	
France	855		586	
Germany, Federal Republic of	542		211	
India	404		10	
Italy	194		17	
Japan	1,028	NA	1	NA
Korea, Republic of	1,361		1	
Mexico	519		46	
Netherlands	872		361	
New Zealand	107		163	
Philippines	1		—	
Poland	542		—	
Romania	42		39	
Sweden	151			
Other	203		40	
Total[3]	8,092	206,984	1,645	57,708

NA Not available.

[1] In 1988, Schedule B No. 480.4500.

[2] Individual country exports furnished by Bureau of the Census will not add to totals.

[3] Total quantity and value f.o.b. mine reported to the Bureau of Mines in 1988 includes ground and unground phosphate rock. Total quantity and value of ground phosphate rock in 1989 were reported by the Bureau of the Census.

TABLE 19

U.S. EXPORTS OF UNGROUND PHOSPHATE ROCK, BY COUNTRY

(Thousand metric tons and thousand dollars)

(HTS No. 2510.10.0000)[1]

Country	1988		1989[p]	
	Quantity[2]	Value	Quantity	Value
Australia	383		282	
Austria	62		32	
Belgium-Luxembourg	388		294	
Brazil	151		—	
Canada	1,186		766	
Finland	85		37	
France	855		92	
Germany, Federal Republic of	542		353	
India	404		420	
Italy	194		88	
Japan	1,028	NA	790	NA
Korea, Republic of	1,361		1,267	
Mexico	519		610	
Netherlands	872		662	
New Zealand	107		42	
Philippines	1		—	
Poland	542		631	
Romania	42		—	
Sweden	151		196	
Other	203		117	
Total[3]	8,092	206,984	[4]6,678	231,282

NA Not available.

[1] In 1988, Schedule B No. 480.4500.

[2] Individual country exports furnished by Bureau of the Census will not add to totals.

[3] Total quantity and value, f.o.b. mine reported to the Bureau of Mines in 1988 includes ground and unground phosphate rock. Total quantity and value in 1989 were reported by the Bureau of the Census.

[4] Data do not add to total because of independent rounding.

other than ownership changes in the United States.

Capacity

The estimates of phosphate rock production capacity as shown in the accompanying table were not significantly changed from those of 1988. With an excess of capacity, there was no incentive to increase capacity.

Reserves

The availability of phosphate resources to support domestic fertilizer production for the U.S. agricultural sector and export demand has been questioned for a number of years. Both pessimistic and optimistic estimates have been made by scientists and businessmen. It appears, however, that the differences between estimates, if made with integrity, were frequently caused by what was being estimated rather than how much was there. Differences may relate to potential availability or currently available phosphate rock. Differences may be found in areas treated, in price assumptions or mining and beneficiation technology, in the quality of phosphate rock for different purposes, in the geologic assurance of existence or measurement, in the data used for estimates, and finally, in the methodology of assessing the resource.

Difficulties in producing compatible phosphate rock resource estimates also occur because of imprecise and confusing technical language. To eliminate the confusion, a sedimentary phosphate rock resource classification system was prepared to permit the differences to be analyzed. The principles of this classification system were presented in *U.S. Geological Survey Circular 831,* published in 1981 and prepared by the U.S. Geological Survey and the U.S. Bureau of Mines to facilitate the assessment of national phosphate rock resources. The criteria developed relate as much as possible to current industrial practice. Because industry practices vary from mine to mine, parameter limits will vary, and tradeoffs are possible. The criteria are guidelines that may be replaced for specific deposits.

As high-grade phosphate rock deposits are depleted, it is probable that technology will change to permit the mining and processing of lower quality phosphate rock. If favorable economics permit, this could change the classification criteria for the resource classes.

The classification system was based on the degree of geologic assurance and the feasibility of economic recovery. Phosphate rock resources were classified as identified or undiscovered. The varying degrees of geologic certainty were expressed as proved, probable, and possible. Resources can be classified according to their degree of economic feasibility. These include economic, marginally economic, and subeconomic resources.

Phosphate economic resources may be profitably extracted and produced under defined investment assumptions that are established or assumed with reasonable certainty. Phosphate reserves are that part of the demonstrated resource that can be profitably extracted or produced at the time of determination.

The phosphate reserve base is defined as that part of an identified phosphate resource that meets specified minimum physical and chemical criteria relating to current mining and production practices, including those for grade, quality, thickness, and depth. The reserve base is the in-place demonstrated resource from which reserves are estimated. It may include those parts of the resource that have a reasonable potential for becoming economically available within planning horizons beyond those that assume proven technology and current economics. Tables 28 and 29 show the United States and world phosphate reserves and reserve base estimates.

TABLE 20

U.S. EXPORTS OF SUPERPHOSPHATES, MORE THAN 40% P_2O_5, BY COUNTRY

(Thousand metric tons and thousand dollars)

(HTS No. 3103.10.0020)[1]

Country	1988		1989	
	Quantity	Value[2]	Quantity	Value[2]
Argentina	3		8	
Australia	(3)		56	
Bangladesh	205		102	
Belgium-Luxembourg	—		—	
Brazil	78		2	
Bulgaria	—		—	
Burma	40		—	
Canada	148		—	
Chile	206		110	
Colombia	13		8	
Costa Rica	10	NA	11	NA
Czechoslovakia	—		—	
Dominican Republic	11		2	
Germany, Federal Republic of	—		67	
Japan	57		48	
Mexico	—		—	
Pakistan	17		—	
Peru	25		21	
Poland	15		—	
Uruguay	4		6	
Other	85		76	
Total	917	140,934	517	149,377

NA Not available.
[1] In 1988, Schedule B No. 480.7050.
[2] All values f.a.s.
[3] Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 21

U.S. EXPORTS OF SUPERPHOSPHATES, LESS THAN 40% P_2O_5, BY COUNTRY

(HTS No. 3103.10.0010)[1]

Country	1988		1989	
	Quantity (metric tons)	Value[2] (thousands)	Quantity (metric tons)	Value[2] (thousands)
Canada	18,868	NA	3,312	
Ecuador	—	—	2,983	
Spain	—	—	6,026	NA
Uruguay	—	—	4,012	
Other	4,302	NA	776	
Total	23,170	NA	17,109	$2,484

NA Not available.
[1] In 1988, Schedule B No. 480.7030.
[2] All values f.a.s.

Source: Bureau of the Census.

OUTLOOK

Mine production plans offer a reasonable guideline on what to expect from phosphate rock mines in future years. It is probably the most reliable method of forecasting future supply. However the industry responded to demand in 1989 and produced about 2 million tons more than was planned. Based on producer's plans, phosphate rock production estimates were 48, 48, 49, 53, 53, and 54 million tons in 1990, 1991, 1992, 1993, 1994, and 1995, respectively. It is probable that this supply scenario will be followed. During this period, some mines will deplete and close, others will be reactivated or remain closed.

In 1988, the Bureau of Mines contracted with Wharton Econometric Forecasting Associates to develop a model for projecting long-term and short-term demand for primary fertilizer nutrients and raw materials. The demand estimates were based on projected trends in world population, harvests of major crops, harvested area, and fertilizer application rates. The report concluded that North American phosphate rock demand will depend on North American phosphate rock production and demand for phosphates. Between 1975 and 1980, phosphate rock demand increased by 6% annually, reaching 38.4 million tons in 1980. However, since 1980, phosphate rock demand declined to 33.9 million tons, an average decline of 1.7% per year. Because North American phosphate fertilizer demand is projected to increase by 20% and world phosphate fertilizer demand is projected to increase by 16% through 1995, North American phosphate rock demand will increase to 41 million tons in 1995. Based on this supply-demand analysis, phosphate rock supply will exceed demand in 1995.

BACKGROUND

The United States phosphate rock industry entered the 1980 decade by producing a record 54.4 million metric tons in 1980, and the outlook for the decade was highly optimistic for the mining industry. The U.S. agriculture

sector drove the demand for phosphate fertilizers to feed an expanding world population. Farm land prices increased as more acreage was planted. Phosphate mining company representatives forecasted substantial new phosphate mining capacity to be developed in the southern extension of the Bone Valley Formation in central Florida.

At the end of 1980, President Carter embargoed grain shipments and phosphates to the U.S.S.R. to retaliate for the U.S.S.R.'s invasion of Afghanistan. By 1982, demand for farm products weakened, and demand for phosphate fertilizers declined substantially in the domestic and export markets. During the economic downturn in 1982, several phosphate rock mines were closed or operated at reduced levels. Annual phosphate rock production declined to 37.4 million tons. The industry began recovering in 1983 with the implementation of the Government's "payment-in-kind" program to attempt to reduce grain inventories and stimulate demand. In the eastern United States, unfavorable economic conditions, environmental concerns, and political attitudes virtually ensured that no new phosphate rock mines would be developed during the rest of the decade.

Although the phosphate mining industry increased production through 1985, the depressed state of the U.S. agriculture sector limited demand. The export market helped the industry survive; however, mines and plants were temporarily closed, some merged, and some closed to reduce inventories and bring about a supply-demand balance. The recession in the phosphate rock mining industry appeared to abate by 1985 when production reached 50.8 million tons. However, in 1986 the phosphate rock mining industry produced only 40.3 million tons as demand remained suppressed. Inventories were controlled by plant closings and reduced operating schedules. Employment declined as the industry attempted to minimize losses. Production stabilized as 41.0 million tons was produced in 1987. The demand for phosphate fertilizers improved in early 1988, but the drought of 1988 reduced phosphate fertilizer consumption. Production rose to 45.4 million tons. The recessionary decade of the 1980's ended for the phosphate rock mining industry in 1989 when 49.8 million tons was produced. Although some forecasters expected demand for phosphate fertilizers to exceed the 51 million tons consumed, production and consumption gains over those of 1988 were modified by continuation of the drought in some areas and excessive moisture in other areas. The export demand for manufactured fertilizers exceeded those of prior years, a windfall that was not expected to reoccur in 1990.

The phosphate rock mining industry exported 7.8 million tons, imported 705,000 tons, and consumed an apparent 42.1 million tons. A summary of the industry's production plans indicated that it would produce 48 million tons in 1989 or about 4% less than the 49.8 million tons actually produced.

U.S. production of elemental phosphorus produced from electric furnaces reached 565 thousand tons in 1969 and has gradually declined since that time. By 1988, production had leveled off at

TABLE 22

U.S. EXPORTS OF DIAMMONIUM PHOSPHATES, BY COUNTRY

(Thousand metric tons and thousand dollars)

(HTS No. 3105.30.0000)[1]

Country	1988		1989	
	Quantity	Value[2]	Quantity	Value[2]
Argentina	92		80	
Australia	133		246	
Belgium-Luxembourg	332		463	
Brazil	60		12	
Canada	256		614	
Chile	90		78	
China	1,778		2,337	
Colombia	160		104	
Costa Rica	29		19	
Dominican Republic	27		43	
Ecuador	35		26	
France	99		54	
Germany, Federal Republic of	31		34	
Guatemala	98		6	
India	582	NA	2,255	NA
Iran	293		128	
Ireland	21		45	
Italy	149		116	
Japan	396		367	
Kenya	53		74	
Mexico	22		51	
New Zealand	23		30	
Pakistan	576		33	
Peru	51		30	
Spain	102		90	
Thailand	46		88	
Turkey	201		268	
Uruguay	34		31	
Venezuela	45		100	
Yugoslavia	39		52	
Other	101		419	
Total	5,954	1,081,048	8,293	1,465,749

NA Not available.

[1] In 1988, Schedule B No. 480.8005.

[2] All values f.a.s.

Source: Bureau of the Census.

TABLE 23

U.S. EXPORTS OF MONOAMMONIUM PHOSPHATES, BY COUNTRY

(Thousand metric tons and thousand dollars)

(HTS No. 3105.40.0000)[1]

Country	1988		1989	
	Quantity	Value[2]	Quantity	Value[2]
Argentina	3		6	
Australia	28		88	
Belgium-Luxembourg	11		10	
Brazil	49		3	
Canada	359		240	
Chile	1		5	
China	52		56	
Colombia	40		35	
Costa Rica	—		—	
Dominican Republic	—		—	
Ecuador	3		3	
France	—		—	
Guatemala	33		12	
Hungary	10		29	
India	—	NA	—	NA
Ireland	—		—	
Italy	96		61	
Japan	82		121	
Kenya	—		—	
Mexico	—		1	
New Zealand	1		5	
Pakistan	—		—	
Peru	—		—	
Saudi Arabia	46		62	
Spain	5		—	
Thailand	10		27	
Turkey	—		—	
Uruguay	3		2	
Venezuela	3		31	
Other	24		12	
Total	[3]857	159,691	809	142,515

NA Not available.

[1] In 1988, Schedule B No. 480.8005.

[2] All values f.a.s.

[3] Data do not add to total shown because of independent rounding.

Source: Bureau of the Census.

about 320 thousand tons per year. The drop in production was attributed to restrictions on the use of phosphate detergents in an attempt to reduce environmental damage to receiving waters. About 85% of U.S. elemental phosphorus production was converted into thermal or furnace-grade phosphoric acid. About 50% of the phosphoric acid was used to produce sodium tripolyphosphate, the detergent builder.

Several processes have been developed to purify wet process phosphoric acid to an acceptable level for some applications normally served by phosphoric acid produced by the thermal process. The purified wet-process phosphoric acid can be used in the production of high-purity products for industrial cleaning markets. Thermal acid will probably continue to be used in electronic applications. A shift to production of more purified phosphoric acid appears probable in North America to reduce costs and minimize the impact on the environment.

Definitions

In Florida and North Carolina, the phosphate ore zone or bed is called the matrix. The industry practice in Florida, North Carolina, and Tennessee is to express production and reserves in terms of concentrated product. Chemical analysis of the product may be reported as percent P_2O_5 or tricalcium phosphate, $Ca_3(PO_4)_2$, also referred to as bone phosphate of lime (BPL).

The phosphate content or grade of phosphate rock is normally reported as percent P_2O_5, determined by chemical analysis. It may also be expressed as percent BPL, reminiscent of the time when bones composed the principal source of phosphate in fertilizer manufacture (percent BPL = 2.1853 × percent P_2O_5). It is the basis on which phosphate rock is sold, almost always as a beneficiated concentrate.

The chemical analysis of pebble, the plus 16-mesh washer product, and the 1 millimeter by 0.1 millimeter flotation concentrates, ranges from 25% to 34% P_2O_5 in Florida mines. Of interest is the percent P_2O_5, or percent BPL, and the CaO, Fe_2O_3, Al_2O_3, and MgO content. For phosphoric acid and DAP phosphate manufacture, a phosphate rock product with a ratio of Fe_2O_3 + Al_2O_3 + MgO to P_2O_5 less than 0.1 is preferred. This product specification can be achieved more easily from deposits in the Bone Valley Formation of central Florida than from deposits in the southern extension of the Bone Valley Formation in south-central Florida.

North Carolina phosphate rock concentrated by single anionic flotation analyzes about 28% P_2O_5 and contains some free silica, which is not particularly detrimental to phosphoric acid production. North Carolina phosphate rock, because of its high level of organic matter and other composition variations, is lower in grade than Florida rock. The organic matter may be burned off by calcining at 790° C to 820° C. Single flotation calcined rock of about 65% to 66% BPL (30% P_2O_5) is produced for captive phosphoric acid manufacture. It produces high-quality acid, but the capacity of the phosphoric acid plant may be reduced by lower filtering rates. Two-stage flotation cal-

TABLE 24

U.S. EXPORTS OF PHOSPHORIC ACID, LESS THAN 65% P_2O_5, BY COUNTRY

(Thousand metric tons and thousand dollars)

(HTS No. 2809.20.0010)[1]

Country	1988		1989	
	Quantity	Value[2]	Quantity	Value[2]
Australia	31		49	
Canada	2		12	
Colombia	13		34	
India	233	NA	455	NA
Indonesia	22		—	
Japan	20		19	
Venezuela	75		110	
Other	38		24	
Total	434	74,998	703	124,074

NA Not available.

[1] In 1988, Schedule B No. 480.7015.

[2] All values f.a.s.

Source: Bureau of the Census.

TABLE 25

U.S. EXPORTS OF ELEMENTAL PHOSPHORUS, BY COUNTRY

(HTS No. 2804.70.0000)[1]

Country	1988		1989	
	Quantity (metric tons)	Value[2] (thousands)	Quantity (metric tons)	Value[2] (thousands)
Brazil	690	$1,348	434	$933
Canada	11	14	38	60
Japan	8,543	12,628	9,758	15,118
Korea, Republic of	3,076	4,486	1,746	2,863
Mexico	5,302	7,407	7,280	8,856
Taiwan	4	26	9	21
Other	1,016	1,630	669	443
Total	18,642	27,539	19,934	28,294

[1] In 1988, Schedule B No. 415.3500.

[2] All values f.a.s.

Source: Bureau of the Census.

cined rock analyzes about 72% BPL (33% P_2O_5) and is sold in the phosphate rock market or converted to clear phosphoric acid.

Phosphate ore mined in Tennessee was washed and classified to produce a sand sized product ranging from 0.044 to 6.35 millimeters. Washer feed ranges from 18% to 25% P_2O_5, and the sand-size product contains 23% to 32% P_2O_5. All of the sand-size product was agglomerated and blended with proportioned quantities of sized coke and quartz pebble before smelting in electric furnaces. The silica and calcium constituents combine to produce a fluid slag, the carbon oxidizes to carbon monoxide gas, and volatilized elemental phosphorus is conducted out of the furnace, condensed in cooling towers with water sprays, and collected under water. The slag and a ferrophosphorus byproduct are tapped periodically from the furnace.

Most Western U.S. phosphate ore was beneficiated by crushing, washing, classifying, and drying. Several mines also used a flotation circuit. The product from the beneficiation plant was normally calcined to reduce the hydrocarbon content before shipment to a chemical plant. To meet the demands of fertilizer plants and electric furnaces, western phosphate rock is classified as + 31% P_2O_5 acid or fertilizer grade; 24% to 31% P_2O_5 furnace grade; 18% to 24% P_2O_5 beneficiation grade; and 10% to 18% P_2O_5 low-grade shale. Acid-grade rock was used directly in fertilizer plants, furnace-grade rock was charged to electric furnaces, beneficiation-grade rock was upgraded to acid grade or furnace feed, and low-grade shales were stockpiled for possible future use.

Products for Trade and Industry

Phosphate rock was the raw material used to manufacture phosphate fertilizer, animal feed supplements, and industrial chemicals.

Manufactured fertilizers, or commercial fertilizers, contained one or more essential plant nutrients and were differentiated from green cover crops, farm manure, and ashes that also qualify under the definition of fertilizer, i.e., to make farming more productive. The primary plant nutrients are nitrogen, phosphorus, and potassium. Unfortunately, the phosphate mineral is very insoluble and, therefore, a poor source of phosphorus for plants. For this reason, phosphate rock is treated with an excess of sulfuric acid to produce merchant-grade, wet-process phosphoric acid that contains 52% to 54% P_2O_5 after water evaporation. It is used to make the monoammonium phosphate and DAP fertilizers and liquid mixed fertilizers.

Furnace-grade phosphoric acid is produced by smelting phosphate rock with fine free coke and silica in an electric furnace. Elemental phosphorus offgas is collected underwater. It is burned and converted to a relatively pure phosphoric acid that is used principally in the detergent and food industries.

Superphosphoric acid is produced by concentrating merchant-grade acid to 68% or 72% P_2O_5. It contains polyphosphates rather than orthophosphates, has the advantage of higher solubility, and can dissolve more impurities when making liquid fertilizers.

Triple superphosphate is produced by treating phosphate rock with phosphoric acid. The product has 44% to 46% P_2O_5 and is manufactured in granular or pow-

TABLE 26

U.S. IMPORTS FOR CONSUMPTION OF PHOSPHATE ROCK AND PHOSPHATE MATERIALS

(Thousand metric tons and thousand dollars)

Phosphatic materials	HTS NO.[1]	1988		1989	
		Quantity	Value[2]	Quantity	Value[2]
Natural calcium[3] phosphates unground	2510.10.0000	r676	r26,310	705	29,878
Natural calcium[3] phosphates ground	2510.20.0000	—	—	(4)	254
Dicalcium phosphate	2835.25.0000	r2	2,688	76	43,184
Phosphorus	2804.70.0000	18	24,837	—	—
Normal superphosphate	3103.10.0010	(4)	69	1	286
Triple superphosphate	3103.10.0020	105	17,271	(4)	22
Diammonium phosphate	3105.30.0000	10	r2,430	14	3,903
Fertilizer containing nitrates and phosphates	3105.51.0000	NA	NA	18	2,736
Phosphoric acid	2809.20.0010	1	r107	(4)	21

r Revised. NA Not available.
[1] Harmonized tariff schedule of the United States.
[2] Declared c.i.f values.
[3] Excludes reported imports from Canada and Israel.
[4] Less than 1/2 unit.

Source: Bureau of the Census.

dered form.

Normal or ordinary superphosphate was for many years the leading commercial fertilizer because of its ease of manufacture; pulverized phosphate rock was mixed with sulfuric acid and cured. The popularity of this fertilizer declined because of its relatively low, 18% to 20% P_2O_5, analysis.

Ammonium phosphate is made by treating phosphoric acid with ammonia. The most popular ammonium phosphate product contains 18% nitrogen and 46% P_2O_5 (18-46-0) and is commonly called DAP. Other ammonium phosphate product compositions are 16-48-0, 11-48-0, and 12-52-0.

Nitrophosphates are produced by reacting nitric acid with phosphate rock to produce a 14% to 22% nitrogen, 10% to 22% P_2O_5, fertilizer.

Phosphorus products used to supplement animal feeds include diammonium and monoammonium phosphates, monohydrate and anhydrous monocalcium phosphate, dihydrate and anhydrous dicalcium phosphate, tricalcium phosphate, phosphoric acid, a number of sodium phosphates, sodium tripolyphosphate, and trisodium phosphate.

Industry Structure

The principal phosphate rock-producing countries in the world in order of decreasing production were the United States, the U.S.S.R., Morocco, China, Tunisia, Jordan, Brazil, and Israel. Thirty-four countries reported producing phosphate rock in 1989. World production was an estimated 162 million tons.

In the United States, phosphate rock was mined in Florida, Idaho, Montana, North Carolina, Tennessee, and Utah. In central Florida, 8 companies operated 14 mines that produced phosphate rock from the Bone Valley Formation. Agrico operated the Payne Creek and Fort Green Mines. CF Industries produced phosphate rock from its Hardee Complex Mine in Hardee County on a reduced operating schedule. Estech Inc. produced phosphate rock from its Silver City Mine and planned to produce in 1990 until the reserve was depleted. C&G Holdings own the Silver City Mine. Gardinier, operated its Fort Meade Mine in Polk County. Seminole purchased the assets of W. R. Grace & Co. in Florida and sold the company to Tosco Corp. in 1989. The company operated the Hookers Prairie Mine. Hopewell Land Partners Ltd. sold its mine to IMC. IMC will recover about 10 million tons of phosphate rock from its Hopewell Mine. IMC reopened its Four Corners Mine in central Florida and planned to pump matrix from its Lonesome deposit in southeast Hillsborough County to Four Corners in 1990. IMC closed the Haynsworth Mine, purchased the Hopewell Mine, and produced phosphate rock from Clear Springs, Kingsford, Noralyn/Phosphoria, and Four Corners Mines. The Lonesome Mine beneficiation plant was idle during the year. Mobil reactivated the Nichols Mine in 1989 and planned to reopen the Big Four Mine in 1990 to coincide with closing the Fort Meade Mine. The South Fort Meade deposit was projected to start producing in 1995 after the Big Four Mine was depleted. USX Agri-Chemical Div. was purchased by Sinochem U.S.A. Inc., was renamed U.S. Agri-Chemical Corp., and continued to mine the Rockland Mine. Nu-Gulf did not operate the Wingate Creek Mine, and it was reported for sale. Occidental operated the Suwannee River and Swift Creek Mines in north Florida to produce superphosphoric acid for export to the U.S.S.R.

In its 1988 annual report, Elf Aquitaine published that Texasgulf produced 4.9 million tons of phosphate rock in that year. Texasgulf installed bucket-wheel excavators to strip overburden in 1989.

The remaining phosphate companies in Tennessee, Occidental Chemical Corp., Columbia, TN, and Rhône-Poulenc (formerly Stauffer Chemical Co.), Mt. Pleasant, TN, mined phosphate rock from Giles, Williamson, and Maury Counties. After sizing and agglomeration, the phosphate rock was smelted in electric furnaces to produce elemental phosphorus.

In Idaho, Rhône-Poulenc produced

TABLE 27

WORLD PHOSPHATE ROCK ANNUAL PRODUCTION CAPACITY, DECEMBER 31, 1989 RATED CAPACITY[1]

(Million metric tons per year)

Country	Capacity
North America:	
Mexico	1.0
United States	60.0
Total	61.0
South America	10.0
Europe:	
U.S.S.R.	36.0
Other	1.0
Total	37.0
Africa:	
Algeria	2.3
Morocco/Sahara	32.0
Senegal	2.1
South Africa, Republic of	4.7
Togo	3.2
Tunisia	10.0
Other	1.2
Total	55.5
Asia:	
China	19.0
Israel	4.0
Jordan	8.0
Korea, North	1.0
Vietnam	1.0
Other	1.0
Total	34.0
Oceania:	
Australia	1.0
Nauru	2.0
Total	3.0
World total	200.5

[1]Includes capacities of operating plants, as well as plants on stand-by basis.

phosphate rock from its Wooley Valley Mine for shipment to its electric furnace plant at Silver Bow, MT. Rhône-Poulenc is planning a purified wet-process plant at Geismar, LA, to increase its capacity of high-purity phosphoric acid. The Conda Partnership mined the Mountain Fuel and Maybie Canyon deposits. The phosphate rock was used in Nu West's fertilizer plant at Conda, ID. Monsanto mined phosphate rock from its Enoch Valley Mine and smelted the rock in its Soda Springs, ID, electric furnaces. J. R. Simplot operated the Gay and Smoky Canyon Mines. A slurry pipeline from the Conda Mine to Conda, ID, will be extended to Pocatello to replace the railroad system. Reserves of the Gay Mine on the Fort Hall Indian Reservation will permit the mine to produce through 1994. Thereafter, production will be increased at Smoky Canyon to supply J. R. Simplot's fertilizer plant demand, and FMC Corp. will develop a new mine in Dry Valley to supply phosphate rock to its Pocatello, ID, electric furnaces.

Chevron produced phosphate rock concentrates from its Vernal, UT, mine. The concentrates were pumped to Rock Springs, WY, for conversion to phosphoric acid and DAP.

Cominco installed a new beneficiation and drying plant to process phosphate ore from its underground mine near Garrison, MT in 1988 and exported to Canada in 1989.

TABLE 28

U.S. PHOSPHATE ROCK RESERVE AND RESERVE BASE ESTIMATES

(Million metric tons)

State	Reserves[1]	Reserve base[2]
Florida	750	2,540
Idaho	90	160
Montana	1	1
North Carolina	390	790
Tennessee	6	10
Utah	—	730
Wyoming	—	210
Total[3]	1,230	4,440

[1]Phosphate rock reserves at a cost less than $40 per ton f.o.b. mine. Costs include capital, operating expenses, taxes, royalties (if applicable), miscellaneous costs, and a 15% rate of return on investments. Costs and resources are as of Jan. 1989, f.o.b. mine.
[2]Reserve base at a cost less than $100 per ton f.o.b. mine. Costs are as defined in footnote 1.
[3]Data may not add to totals shown because of independent rounding.

Tariffs and Taxes

Phosphate rock and phosphate fertilizers were imported duty free. The phosphate industry was subject to the usual local, State, and Federal taxes. In addition, a severance tax of $1.35 per metric ton ($1.49 per short ton) was applied in Florida in 1989; 2% of the net value in Idaho, and $25 plus 0.5% of the gross value over $5,000 in Montana was assessed. A history of the severance tax in Florida indicates the tax rose from $0.102 per ton in 1971 to a peak of $2.52 per ton in 1985. The Florida severance tax is currently based on $1.35 per ton at point of severance, then was adjusted with the Producers Price Index to $1.54 per ton in 1989.

Technology

Production of phosphate rock was similar in each of the 14 operating mines in Florida. The phosphorus-containing component in the matrix is apatite, a calcium phosphate containing varying amounts of carbonates and fluorides. The phosphate bearing matrix varies from 1.5 to 6.1 meters in thickness under an overburden of sand, clay, and a leach zone. The total overburden thickness, including the leach zone, ranges from 5.6 to 8.6 meters.

Mine planning was accomplished by taking core samples and processing the cores through bench-scale washing and flotation procedures, similar to those of a commercial plant to determine recoveries, quality, and product grade. Stripping overburden and mining matrix was accomplished with electric walking draglines with 32-cubic-meter or larger buckets on 68 meter booms. Mining cuts, after overburden was progressively stripped, were 900 meters in length and 90-meters wide. Pumps were used to prevent the pits from flooding. The dragline fed matrix to a sump where water monitors operating at a pressure of 17 kilograms per square centimeter slurried the matrix. It was pumped in 900-meter stages in steel pipe to the washing plant.

Washing plants were designed to size the material pumped to them. Trommel screens were frequently used to scrub the phosphate from the sand and clay matrix and reject material over 19 millimeters. The trommel undersize was screened at 14 mesh. The 19 millimeter by 14-mesh material was further washed on screens and log washers to liberate the phosphate mineral. Minus 14 mesh material reported to cyclones. The separated cyclone overflow, minus 150-mesh colloidal material, was pumped to settling ponds. The flotation process was used to separate the sand from the phosphate mineral. The flotation feed was conditioned with fatty acids to create a hydrophobic surface, and the phosphate mineral was floated to produce a rougher

concentrate. The rougher concentrate was treated with sulphuric acid to strip the fatty acids. An amine flotation circuit was used to float carryover sand, and the phosphate mineral was depressed. Flotation concentrates were conveyed into silos for dewatering and loaded into railroad cars for export or a fertilizer plant. The beneficiation plants' products, pebble and concentrate, were used in Florida chemical fertilizer plants or barged to fertilizer plants on the Mississippi River.

Sulfur, either recovered or Frasch, was received from heated ships at Tampa terminals or receiving terminals on the Mississippi River. In Florida, liquid sulfur was pumped into road tankers that delivered molten sulfur to the chemical plants. The liquid sulfur was burned to produce sulfuric acid. The phosphate rock was digested in sulfuric acid to produce phosphoric acid and waste phosphogypsum. The phosphoric acid was passed through evaporators to increase the phosphorus pentoxide concentration to the commercial grade, 54% P_2O_5. Phosphoric acid was reacted with anhydrous ammonia to produce DAP or reacted with phosphate rock concentrates to produce triple superphosphate.

Mining procedure was similar in North Carolina; however, the overburden was about 30 meters, considerably thicker. Hydraulic dredges were used to remove the top 12 meters of overburden. The dredges were replaced in 1989 with bucketwheel excavators. Draglines were used to strip the remaining overburden and mine approximately 12 meters of matrix. The matrix was beneficiated to produce a 67%-BPL product. Some of this product was calcined to remove organic compounds, carbon dioxide, and water and raise the grade to 72% BPL.

All phosphate rock in the Western States of Idaho and Utah was surface mined. There is an underground mine in Montana. Operators in southeastern Idaho principally used scrapers and bulldozers to remove overburden and mine the ore. Main bed ore for consumption in wet-process phosphoric acid plants and adjacent bedded furnace shale for electric furnace feed were mined selectively. In Utah, the phosphate rock was quarried after the limestone caprock was drilled, blasted, and trucked to waste. Underground ore in Montana was mined, crushed, sized, and dried before rail shipment to Canada. Ore mined in the Western States was transported by truck or rail to beneficiation plants. Phosphate rock concentrates were moved by truck, rail, or slurry pipeline to chemical fertilizer plants. Electric furnace feed was received by truck or rail transport.

Phosphate rock in the Western States was beneficiated for electric furnace feed and to produce wet-process phos-

TABLE 29

WORLD PHOSPHATE ROCK RESERVE AND RESERVE BASE

(Million metric tons)

	Number of deposits	Reserves[1]	Reserve base[2]
North America:			
Canada	1	50	50
Mexico	2	10	110
United States	94	1,230	4,440
Total	97	1,290	4,600
South America:			
Brazil	11	330	370
Colombia	1	—	100
Peru	1	310	310
Venezuela	1	—	10
Total	14	640	790
Europe:			
Finland	1	—	70
Turkey	1	30	30
U.S.S.R.	11	1,330	1,330
Total	13	1,360	1,430
Africa:			
Algeria	1	240	240
Egypt	5	—	760
Morocco	10	4,950	20,490
Western Sahara	1	950	950
Senegal	2	—	160
South Africa, Republic of	1	2,530	2,530
Togo	12	—	60
Tunisia	11	—	270
Total	43	8,670	25,460
Asia:			
China	6	210	210
Christmas Island	1	10	10
Israel	4	—	180
Jordan	3	90	480
Syria	2	190	190
Other	6	30	330
Total	22	530	1,400
Oceania:			
Australia	5	90	590
Nauru	1	5	5
Total	6	95	595
World total	195	12,585	34,275

[1] Phosphate rock reserves at a cost less than $40 per ton f.o.b. mine. Costs include capital, operating taxes, royalties (if applicable), miscellaneous costs and a 15% rate of return on investment. Costs and resources are as of Jan. 1989, f.o.b. mine.
[2] Reserve base at a cost less than $100 per ton. Costs are as defined in footnote 1.

TABLE 30

PHOSPHATE ROCK, BASIC SLAG AND GUANO: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand metric tons)

Commodity and country[2]	Gross weight					P_2O_5 content				
	1985	1986	1987	1988[p]	1989[e]	1985	1986	1987	1988[p]	1989[e]
Phosphate rock:										
Algeria	1,207	1,203	1,073	1,332	1,223	e381	e380	e336	e404	371
Australia	33	34	11	13	8	7	7	2	2	1
Brazil	4,214	4,509	4,777	e4,672	3,580	1,475	1,620	1,694	e1,663	1,290
Chile	7	7	10	9	10	1	1	e1	e1	1
China[e]	6,970	6,700	9,000	15,000	15,500	1,882	1,810	2,700	4,050	4,100
Christmas Island (Indian Ocean)	1,187	880	842	—	—	418	310	e295	—	—
Colombia	23	27	34	e35	30	6	7	8	e9	8
Egypt	e1,074	1,271	1,167	e1,146	1,146	270	315	e312	e293	293
Finland	512	527	e553	584	560	189	195	e195	215	200
India	929	667	679	678	700	307	222	226	r e224	231
Indonesia	1	1	3	1	3 11	(r 4)	(r 4)	1	(4)	4
Iraq[e]	1,000	1,000	1,500	1,273	1,300	218	218	330	382	385
Israel	4,076	3,673	3,798	3,479	3,922	1,210	1,110	e1,214	e1,092	1,231
Jordan	6,067	6,249	6,800	6,611	6,000	2,010	2,072	2,260	e1,868	1,800
Korea, North[e]	500	500	500	500	500	160	160	160	160	160
Mali	7	3	8	10	10	e2	e1	e2	e2	2
Mexico[5]	787	747	689	842	851	236	224	207	253	255
Morocco[6]	20,737	21,178	e20,000	25,015	24,400	e6,574	e6,714	e6,650	8,061	8,000
Nauru	1,508	1,494	1,376	1,540	1,500	e581	e575	e530	e593	590
Pakistan	—	50	32	r e35	35	—	16	10	e10	10
Peru	12	5	61	13	13	e4	2	20	r e4	4
Philippines	6	2	e8	7	7	2	1	e2	e2	2
Senegal[7]	1,814	1,850	1,874	2,326	2,273	e617	e641	e680	r e801	783
South Africa, Republic of	2,433	2,920	2,623	e2,850	2,900	e883	e1,060	e950	e1,010	1,040
Sri Lanka	14	15	e21	23	25	5	5	e7	7	8
Sweden	187	192	e221	142	160	74	72	e82	52	60
Syria	1,270	1,606	1,986	2,342	2,250	380	485	606	715	690
Tanzania	15	e10	18	4	5	e4	e3	r e5	r e1	2
Thailand	4	5	5	8	9	1	1	2	e2	3
Togo	2,452	2,314	2,644	3,464	3 3,355	890	840	e960	e1,257	1,208
Tunisia	4,530	5,951	e6,390	6,103	6,100	e1,303	e1,712	e1,836	e1,813	1,800
Turkey	e37	3	19	74	3 84	e12	e1	e6	e23	26
U.S.S.R.[e]	33,750	33,900	34,100	r 34,400	34,400	10,650	10,700	10,750	r 10,850	10,850
United States	50,835	38,710	40,954	45,389	3 48,866	15,674	11,857	12,491	13,833	3 14,893
Vietnam[e]	516	530	300	r 330	400	170	175	105	r 115	140
Zimbabwe, concentrate	135	136	155	125	135	e47	r e47	e54	r e44	47
Total	r 148,849	r 138,869	144,231	160,375	162,268	r 46,643	r 43,559	45,689	49,811	50,488
Basic (Thomas converter) slag:										
Argentina	e1	(4)	(4)	(e 4)	(4)	(e 4)	(e 4)	(e 4)	(e 4)	(4)
Belgium[e]	3 143	180	175	170	165	3 26	32	32	31	30
Egypt[e]	10	8	8	8	8	2	2	2	2	2
France	1,165	855	r e555	r e555	500	210	154	r e100	r e100	90
Germany, Federal Republic of	491	374	e370	e400	400	67	54	r e50	r e45	45

See footnotes at end of table.

TABLE 30—Continued

PHOSPHATE ROCK, BASIC SLAG AND GUANO: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand metric tons)

Commodity and country[2]	Gross weight					P_2O_5 content				
	1985	1986	1987	1988[p]	1989[e]	1985	1986	1987	1988[p]	1989[e]
Basic (Thomas converter) slag—Continued										
Luxembourg	701	620	542	[e]540	550	126	112	98	[e]95	99
United Kingdom	[e]4	—	—	—	—	[e]1	—	—	—	—
Total	2,515	2,037	1,650	1,673	1,623	432	[r]354	282	273	266
Guano:										
Chile	3	8	6	4	4	([4])	1	[e]1	([e 4])	([4])
Kenya	([4])	—	—	—	—	([4])	—	—	—	—
Philippines	1	3	[e]1	1	2	([4])	1	([e 4])	([e 4])	([4])
Seychelles Islands[e]	5	5	5	5	5	2	2	2	2	2
Total	9	[r]16	12	10	11	2	[r]4	3	2	2

[e] Estimated. [p] Preliminary. [r] Revised.

[1] Table includes data available through May 30, 1990. Data for major phosphate rock producing countries derived in part from the International Fertilizer Industry Association; other figures are from official country sources where available.

[2] In addition to the countries listed, Belgium and Uganda may have produced small quantities of phosphate rock and Namibia may have produced small quantities of guano, but output is not officially reported, and available information is inadequate for formulation of reliable estimates of output levels.

[3] Reported figure.

[4] Less than 1/2 unit.

[5] Includes only output used to manufacture fertilizers.

[6] Production from Western Sahara area included with Morocco.

[7] Does not include aluminum phosphate production, gross weight, in thousand tons: 1985—355; 1986—131; 1987—191; 1988—119; and 1989—100 (estimated).

phoric acid. The technology was similar to that of Florida and Tennessee, although plant flowsheets were tailored to fit the characteristics of each deposit. Western phosphate rock used to produce phosphoric acid was calcined to reduce hydrocarbon levels. Phosphate rock, as mined or beneficiated, was agglomerated before charging electric furnaces to produce elemental phosphorus.

In Tennessee, 150,000- to 200,000-ton ore bodies were stripped of overburden and mined with small draglines. The small dragline bucket was able to remove phosphate bearing ore between limestone crevices and cones (cutters) in the bedrock and light enough to be easily transported by low-boy from one deposit to the next selected for mining. Bulldozers were used to clear access roads to the deposit and remove topsoil and clay overburden. Trucks loaded by dragline moved ore to either a field washer, a railroad loading tipple, or a washer at the electric furnace plant.

Tennessee phosphate rock was beneficiated by washing through a 25-centimeter grizzly screen. The screen undersize was passed through a series of log washers, scrubbers, screens, and cyclones to produce a 0.044- to 6.35- millimeter sand product. Washer feed ranged from 18% to 25% P_2O_5, and the sand concentrate analysis ranged from 23% to 32% P_2O_5. The sand concentrate was nodulized in rotary kilns to convert the sand to 1.9- to 5.1-centimeter nodules, which, after screening to remove oversize and undersize material, were charged to electric furnaces with fine free coke and quartz pebbles to produce elemental phosphorus.

[1] All quantities are in metric tons unless otherwise specified.